

WHAT IS CLAIMED IS:

1. An apparatus comprising:

5 a tunable optical element operable to:
 - receive a first input signal at an incidence angle;
 - receive a second input signal;
 - separate the first input signal into a first beam having a first optical path length and a second beam having a second optical path length, wherein the difference between the first optical path length and the second optical path length is based in part upon the incidence angle of the first input signal; and
 - separate the second input signal into a third beam and a fourth beam;

10 and

15 a reflective element operable to reflect the first beam, the second beam, the third beam, and the fourth beam such that at least a portion of the beams interfere to produce an output signal, wherein the output signal comprises wavelength channels of the first input signal combined with wavelength channels of the second input signal.

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2. The apparatus of Claim 1, wherein the tunable optical element comprises:

a first plate having a reflective region; and

25 a second plate having a partially reflective region and arranged a predetermined distance from the first plate;

wherein:

30 the first input signal is incident upon the partially reflective region of the second plate at the incidence angle to produce the first beam and the second beam;

the first beam is processed to define at least a portion of the first optical path length; and

the second beam is processed to define at least a portion of the second optical path length.

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3. The apparatus of Claim 2, wherein:

the first beam is transmitted by the partially reflective region of the second plate toward the reflective element to define at least a portion of the first optical path length; and

10 the second beam is reflected by the partially reflective region of the second plate and the reflective region of the first plate to define at least a portion of the second optical path length.

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4. The apparatus of Claim 2, wherein:

the first beam is reflected by the partially reflective region of the second plate toward the reflective element to define at least a portion of the first optical path length; and

20 the second beam is transmitted by the partially reflective region of the second plate and reflected by the reflective region of the first plate to define at least a portion of the second optical path length.

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5. The apparatus of Claim 2, wherein the distance between the first plate and the second plate is based upon a predetermined difference between the first optical path length and the second optical path length.

6. The apparatus of Claim 2, wherein the incidence angle of the first input signal is adjusted to tune the difference between the first optical path length and the second optical path length.

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7. The apparatus of Claim 6, wherein the incidence angle is adjusted by adjusting the optical path of the first input signal with respect to the tunable optical element.

5 8. The apparatus of Claim 6, wherein the incidence angle is adjusted by rotating the tunable optical element with respect to the optical path of the first input signal.

9. The apparatus of Claim 2, wherein:
10 a portion of the distance between the first plate and the second plate is filled by a material having a particular index of refraction; and
the difference between the first optical path length and the second optical path length is based in part upon the index of refraction of the material.
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10. The apparatus of Claim 9, wherein the index of refraction is adjusted to tune the difference between the first optical path length and the second optical path length.

20 11. The apparatus of Claim 2, wherein:
the reflective element reflects the first beam and the second beam back toward the tunable optical element; and
the first beam interferes with the second beam at the partially reflective region to introduce a phase shift between the first beam and
25 the second beam.

12. The apparatus of Claim 2, wherein:
the reflective element reflects the third beam and the fourth beam back toward the tunable optical element; and

the third beam interferes with the fourth beam at the partially reflective region to introduce a phase shift between the third beam and the fourth beam.

5 13. The apparatus of Claim 1, wherein adjusting the difference between the first optical path length and the second optical path length adjusts the spacing between the wavelength channels associated with the output signal.

10 14. The apparatus of Claim 1, wherein the reflective element comprises a mirror operable to reflect back to the tunable optical element the first beam and the second beam.

15 15. The apparatus of Claim 1, wherein the reflective element comprises:

 a mirror operable to reflect back to the tunable optical element one of the first beam and the second beam; and

 a resonator operable to reflect back to the tunable optical element the other of the first beam and the second beam.

20 16. The apparatus of Claim 1, wherein the reflective element comprises:

 a first resonator operable to reflect back to the tunable optical element one of the first beam and the second beam; and

25 a second resonator operable to reflect back to the tunable optical element the other of the first beam and the second beam.

17. The apparatus of Claim 16, wherein:
the first resonator has a first center wavelength; and
the second resonator has a second center wavelength that is
offset relative to the first center wavelength by approximately one half
5 of the free spectral range of the first resonator such that the
resonance frequencies of the second resonator are matched to the
anti-resonance frequencies of the first resonator.

18. The apparatus of Claim 16, wherein:
10 the first resonator has a partially reflective front surface and a
highly reflective back surface spaced a first optical thickness from the
front surface;
the second resonator has a partially reflective front surface and
a highly reflective back surface spaced a second optical thickness
15 from the front surface; and
the difference between the optical thicknesses of the first and
second resonators is approximately equal to one-quarter wavelength.

19. The apparatus of Claim 1, wherein the tunable optical
20 element comprises a first tunable optical element, the apparatus
further comprising a second tunable optical element.

20. The apparatus of Claim 19, wherein the second tunable
optical element comprises:
25 a first plate having a partially reflective region; and
a second plate having a reflective region and arranged a
predetermined distance from the first plate;
wherein the first beam interferes with the second beam at the
partially reflective region to introduce a phase shift between the first
30 beam and the second beam.

21. The apparatus of Claim 19, wherein the second tunable optical element comprises:

- a first plate having a partially reflective region; and
 - 5 a second plate having a reflective region and arranged a predetermined distance from the first plate;
- wherein the third beam interferes with the fourth beam at the partially reflective region to introduce a phase shift between the third beam and the fourth beam.

22. A method for processing optical signals, comprising:
receiving a first input signal at an incidence angle;
receiving a second input signal;
separating the first input signal into a first beam having a first
5 optical path length and a second beam having a second optical path
length, wherein the difference between the first optical path length and
the second optical path length is based in part upon the incidence
angle of the first input signal;
separating the second input signal into a third beam and a
10 fourth beam; and
interfering at least a portion of the beams to produce an output
signal, wherein the output signal comprises wavelength channels of
the first input signal combined with wavelength channels of the second
input signal.
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23. The method of Claim 22, wherein separating the first
input signal comprises:
transmitting a first portion of the first input signal to generate
the first beam; and
20 reflecting a second portion of the first input signal to generate
the second beam.
24. The method of Claim 23, wherein reflecting a second
portion of the input signal comprises:
reflecting a second portion of the first input signal at a partially
25 reflective interface to generate the second beam; and
reflecting the second beam at a totally reflective interface such
that the second beam and the first beam propagate along substantially
parallel optical paths.
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25. The method of Claim 24, wherein:

the partially reflective interface is associated with a first plate;

the totally reflective interface is associated with a second plate;

and

5 the distance between the first plate and the second plate is based upon a predetermined difference between the first optical path length and the second optical path length.

10 26. The method of Claim 22, further comprising adjusting the incidence angle of the first input signal to tune the difference between the first optical path length and the second optical path length.

15 27. The method of Claim 26, wherein adjusting the incidence angle comprises adjusting the optical path of the first input signal.

28. The method of Claim 25, wherein:

a portion of the distance between the first plate and the second plate is filled by a material having a particular index of refraction; and

20 the difference between the first optical path length and the second optical path length is based in part upon the index of refraction of the material.

25 29. The method of Claim 28, further comprising adjusting the index of refraction to tune the difference between the first optical path length and the second optical path length.

30. The method of Claim 22, wherein interfering comprises interfering the first beam with the second beam to introduce a phase shift between the first beam and the second beam.

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31. The method of Claim 22, wherein:
the first input signal comprises a first input spectral band;
the second input signal comprises a second input spectral
band; and
- 5 the output signal comprises an output spectral band that
includes at least portions of the first input spectral band and the
second input spectral band.
32. The method of Claim 22, further comprising adjusting the
10 difference between the first optical path length and the second optical
path length to adjust the spacing between the wavelength channels
associated with the output signal.
33. The method of Claim 22, further comprising reflecting
15 the first beam and the second beam using a mirror.
34. The method of Claim 22, further comprising:
reflecting one of the first beam and the second beam using a
mirror; and
- 20 reflecting the other of the first beam and the second beam
using a resonator.
35. The method of Claim 22, further comprising:
reflecting one of the first beam and the second beam using a
25 first resonator; and
reflecting the other of the first beam and the second beam
using a second resonator.
36. The method of Claim 35, wherein:
30 the first resonator has a first center wavelength; and

the second resonator has a second center wavelength that is offset relative to the first center wavelength by approximately one half of the free spectral range of the first resonator such that the resonance frequencies of the second resonator are matched to the anti-resonance frequencies of the first resonator.

37. The method of Claim 35, wherein:

the first resonator has a partially reflective front surface and a highly reflective back surface spaced a first optical thickness from the
10 front surface;

the second resonator has a partially reflective front surface and a highly reflective back surface spaced a second optical thickness from the front surface; and

the difference between the optical thicknesses of the first and second resonators is approximately equal to one-quarter wavelength.

38. The method of Claim 22, wherein the output signal comprises a first output signal and further comprising:

receiving a second output signal; and

20 processing the first output signal and the second output signal to generate a third output signal, wherein the third output signal comprises wavelength channels of the first output signal combined with wavelength channels of the second output signal.

39. An optical system, comprising a multiplexer network operable to multiplex a plurality of input WDM signals into at least one output WDM signal, the multiplexer network comprising:

a tunable optical element operable to:

- 5 receive a first intermediate input signal at an incidence angle;
- receive a second intermediate input signal;
- separate the first intermediate input signal into a first beam having a first optical path length and a second beam having a second optical path length, wherein the difference between the first optical path length and the second optical path length is based in part upon the incidence angle of the first intermediate input signal; and
- 10 separate the second intermediate input signal into a third beam and a fourth beam;
- 15 and
- a reflective element operable to reflect the first beam, the second beam, the third beam, and the fourth beam such that at least a portion of the beams interfere to produce an intermediate output signal, wherein the intermediate output signal comprises wavelength channels of the first intermediate input signal combined with wavelength channels of the second intermediate input signal.

40. The optical system of Claim 39, further comprising a demultiplexer network operable to demultiplex an input WDM signal into a plurality of wavelength channels, wherein:

- the first intermediate input signal comprises a first subset of the plurality of wavelength channels; and
- the second intermediate input signal comprises a second subset of the plurality of wavelength channels.

41. The optical system of Claim 40, further comprising an optical component communicatively coupled to the demultiplexer network and operable to process a portion of the wavelength channels.

42. The system of Claim 39, wherein the tunable optical element comprises:

10 a first plate having a reflective region; and
a second plate having a partially reflective region and arranged a predetermined distance from the first plate;

wherein:

15 the intermediate input signal is incident upon the partially reflective region of the second plate at the incidence angle to produce the first beam and the second beam;

the first beam is processed to define at least a portion of the first optical path length; and

the second beam is processed to define at least a portion of the second optical path length.

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43. The system of Claim 42, wherein:

the first beam is transmitted by the partially reflective region of the second plate toward the reflective element to define at least a portion of the first optical path length; and

25 the second beam is reflected by the partially reflective region of the second plate and the reflective region of the first plate to define at least a portion of the second optical path length.

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44. The system of Claim 42, wherein:

the first beam is reflected by the partially reflective region of the second plate toward the reflective element to define at least a portion of the first optical path length; and

5 the second beam is transmitted by the partially reflective region of the second plate and reflected by the reflective region of the first plate to define at least a portion of the second optical path length.

45. The system of Claim 42, wherein the first plate is
10 arranged parallel to the second plate.

46. The system of Claim 42, wherein the distance between the first plate and the second plate is based upon a predetermined difference between the first optical path length and the second optical
15 path length.

47. The system of Claim 42, wherein the incidence angle of the intermediate input signal is adjusted to tune the difference between the first optical path length and the second optical path
20 length.

48. The system of Claim 47, wherein the incidence angle is adjusted by adjusting the optical path of the intermediate input signal with respect to the tunable optical element.
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49. The system of Claim 47, wherein the incidence angle is adjusted by rotating the tunable optical element with respect to the optical path of the intermediate input signal.

50. The system of Claim 42, wherein:
a portion of the distance between the first plate and the second
plate is filled by a material having a particular index of refraction; and
the difference between the first optical path length and the
5 second optical path length is based in part upon the index of refraction
of the material.

51. The system of Claim 50, wherein the index of refraction
is adjusted to tune the difference between the first optical path length
10 and the second optical path length.

52. The system of Claim 39, wherein:
the first beam emitted by the tunable optical element follows a
first optical path toward the reflective element;
15 the second beam emitted by the tunable optical element follows
a second optical path toward the reflective element; and
the first optical path is substantially parallel with the second
optical path.

20 53. The system of Claim 39, wherein the difference
between the first optical path length and the second optical path
length is substantially independent from the distance between the
tunable optical element and the reflective element.

25 54. The system of Claim 42, wherein:
the reflective element reflects the first beam and the second
beam back toward the tunable optical element; and
the first beam interferes with the second beam at the partially
reflective region to introduce a phase shift between the first beam and
30 the second beam.

55. The system of Claim 39, wherein:
the intermediate input signal comprises an input spectral band;
the first intermediate output signal comprises a first subset of
5 the input spectral band; and
the second intermediate output signal comprises a second
subset of the input spectral band that is complementary to the first
subset of the input spectral band.
- 10 56. The system of Claim 55, wherein:
the intermediate input signal comprises a plurality of
wavelength channels associated with the input WDM signal;
the first subset of the input spectral band comprises even
wavelength channels; and
- 15 the second subset of the input spectral band comprises odd
wavelength channels.
- 20 57. The system of Claim 39, wherein adjusting the difference
between the first optical path length and the second optical path
length adjusts the spacing between the wavelength channels
associated with the first intermediate output signal and the second
intermediate output signal.
- 25 58. The system of Claim 39, wherein the reflective element
comprises a mirror operable to reflect back to the tunable optical
element the first beam and the second beam.

59. The system of Claim 39, wherein the reflective element comprises:

a mirror operable to reflect back to the tunable optical element one of the first beam and the second beam; and

5 a resonator operable to reflect back to the tunable optical element the other of the first beam and the second beam.

60. The system of Claim 59, wherein the resonator comprises a Gires-Tournois resonator.

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61. The system of Claim 42, wherein:

the reflective element comprises a resonator having an optical thickness; and

15 the distance between the first plate and the second plate is based in part upon the optical thickness of the resonator.

62. The system of Claim 39, wherein the reflective element comprises:

20 a first resonator operable to reflect back to the tunable optical element one of the first beam and the second beam; and

a second resonator operable to reflect back to the tunable optical element the other of the first beam and the second beam.

63. The system of Claim 62, wherein:

25 the first resonator has a first center wavelength; and

the second resonator has a second center wavelength that is offset relative to the first center wavelength by approximately one half of the free spectral range of the first resonator such that the resonance frequencies of the second resonator are matched to the 30 anti-resonance frequencies of the first resonator.

64. The system of Claim 62, wherein:

the first resonator has a partially reflective front surface and a highly reflective back surface spaced a first optical thickness from the
5 front surface;

the second resonator has a partially reflective front surface and a highly reflective back surface spaced a second optical thickness from the front surface; and

the difference between the optical thicknesses of the first and
10 second resonators is approximately equal to one-quarter wavelength.

65. The system of Claim 64, wherein the first optical thickness is selected to produce a desired center frequency and free-spectral range such that even wavelength channels in the
15 intermediate input signal are included in the first intermediate output signal and odd wavelength channels in the intermediate input signal are included in the second intermediate output signal.

66. The system of Claim 39, wherein the tunable optical element comprises a first tunable optical element, the reflective element further comprising a second tunable optical element.
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67. The system of Claim 66, wherein the second tunable optical element comprises:

a first plate having a partially reflective region; and
25 a second plate having a reflective region and arranged a predetermined distance from the first plate;
wherein the first beam interferes with the second beam at the partially reflective region to introduce a phase shift between the first
30 beam and the second beam.

68. The system of Claim 67, wherein:
- the first beam is incident upon the partially reflective region to define at least a portion of the first optical path length; and
- 5 the second beam is reflected by the reflective region toward the partially reflective region to define at least a portion of the second optical path length.
69. The system of Claim 67, wherein the distance between
10 the first plate and the second plate is based upon a predetermined difference between the first optical path length and the second optical path length.
70. The system of Claim 67, wherein the second tunable
15 optical element is rotatable to adjust the difference between the first optical path length and the second optical path length.
71. The system of Claim 67, wherein:
- a portion of the distance between the first plate and the second
20 plate is filled by a material having a particular index of refraction; and
- the difference between the first optical path length and the second optical path length is based in part upon the index of refraction of the material.
- 25 72. The system of Claim 71, wherein the index of refraction is adjusted to tune the difference between the first optical path length and the second optical path length.